DRAFT TECHNICAL MEMORANDUM

Date: March 7, 2006

Prepared For: Rose Marie Caraway, USEPA Region IX

Prepared By: T N & Associates
Michael Berman, P E.
John Wingate, P.E.

**Re: Re-evaluation of Vapor Phase Treatment of Vinyl Chloride Via GAC and Potassium Permanganate Impregnated Media
Pemaco Superfund Site
5050 East Slauson Avenue, Maywood, California.**

Cc: John Hartley, United States Army Corps of Engineers

1.0 INTRODUCTION

T N & Associates, Inc. (TN&A) has prepared this Technical Memorandum to present updated technical data regarding the treatment of vapor phase vinyl chloride (VC) using granular activated carbon (GAC) and potassium permanganate impregnated ($KMnO_4$) media for application at the Pemaco Superfund Site (Site).

Research documentation for vapor phase treatment technologies was previously presented in the Final Feasibility Study (TN&A, Feb. 2004) for the Pemaco Superfund Site, and later in the Technical Memo, "Descriptions and Discussion of Various Ex-Situ Vapor Treatment Alternatives"(TN&A, Sept. 8, 2004). The conceptual design presented in the Final Feasibility Study and supported by the Technical Memo, assumed that initial high mass loading of Volatile Organic Compounds (VOCs) extracted during the first year of remediation would be more effectively and efficiently treated using a thermal technology. Additionally, due to community concerns and USEPA direction, it was determined that a flameless thermal oxidizer (FTO) would be appropriate for use at Pemaco. Its was estimated that after the first year, the mass loading would be significantly reduced and switching from the FTO as the primary vapor phase treatment system to GAC as the primary vapor treatment system would be safe and more cost effective. In addition, 1,4-Dioxane and VC were cited as compounds that would be problematic to treat via GAC during the first year of operation.

Since the Final Feasibility Study and Technical Memo, case study data has become available from other consultants/contractors who have been using GAC followed by $KMnO_4$ media for their primary vapor phase treatment system for VOCs with VC. In addition, new GAC treatability data, in the forms of isotherms and case studies, has become available. TN&A has evaluated the new information and its applicability to the Pemaco site in the following sections A summary of the applicability of this information is present in the Conclusions section.

2.0 TREATABILITY OF VINYL CHLORIDE VIA GAC AND $KMnO_4$ MEDIA

Data presented in the Final Feasibility Study and Technical Memo regarding the treatment of vapor phase VC via GAC indicated that due to VC's low GAC adsorption characteristics, primary vapor treatment using the FTO was justified. Other characteristics of VC, which include a high vapor pressure and Henry's constant, are relevant to understanding VC's tendency to change (from other phases) to the vapor phase and accumulate in the soil pores. At the onset of soil vapor extraction, an associated spike in VC concentrations would be expected followed by an equally steep decrease in concentrations (after several months) as soil pore volumes are flushed with surrounding air. Hence, the conceptual design model prescribes a switch from FTO as the primary vapor phase treatment system to GAC as the primary vapor phase treatment system after the first year, when VC concentrations would be mostly depleted.

Recently, consultants/contractors have been using GAC followed by $KMnO_4$ media as their primary treatment method for removing VC from the vapor phase. In this treatment method, GAC is placed first in the treatment train to remove the bulk of the VOCs and the $KMnO_4$ media is placed after the GAC to oxidize VC and any other VOCs that are not treated by the carbon. TN&A contacted the vendors Baker Filtration, U.S. Filters, and Calgon Carbon to obtain technical and operational specifications regarding treatment of vapor phase VC. In summary, two of the vendors recommended a $KMnO_4$ media for the removal of vapor phase VC and one offered isotherm data that indicates that virgin coconut carbon can be effective for the removal of vapor phase VC. The vendor information is provided as follows:

Baker Filtration (formerly Cameron Environmental, Inc)

Baker Filtration offers a media called "CEI-KMN Media" designed to oxidize VC and other gaseous pollutants in the vapor phase. Based on the specifications (attached), the CEI-KMN Media consists of a molecular sieve substrate that is impregnated with 6% potassium permanganate. Baker Filtrations stated that for every 1 pound of VC removal, approximately 70 pounds of the CEI-KMN Media will be consumed. Baker Filtrations estimated that 1.7 pounds of CEI-KMN Media will be consumed per day of operations (assuming 0.16 ppmv VC and 270 scfm flow rate)[1] for the perched zone and 73.5 pounds of CEI-KMN Media consumed per day (assuming 21.75 ppmv VC and 224 scfm flow rate)[2] for the A and B exposition zones (see attached email correspondence). Baker Filtrations stated that the media was manufactured by Hydrosil. The turnkey costs for the media was quoted at $1.45 per pound (assuming non-hazardous waste disposal). Baker Filtrations stated that compounds such as alcohols and acetone that are known to be present at Pemaco can also react with; and therefore, consume the $KMnO_4$ media (see attached "$KMnO_4$ Reactivity and Capacity Table" for complete list). TN&A contacted Tom Kerscher with Envent Corporation and Brian Dean with Earth Tech as a reference for Baker Filtration's CEI-KMN Media (see Earth Tech Case Study).

U.S. Filters

U.S. Filters offers a $KMnO_4$ media designed to oxidize VC and other gaseous pollutants in the vapor phase which appears to be the same Hydrosil product provided to Baker Filtration (specification attached). Please note that in the attached email correspondence, U.S. Filters inadvertently referred to the potassium permanganate impregnated zeolite media as impregnated carbon. U.S. Filters stated that for every 0.3 pound of VC removal, approximately 100 pounds of impregnated carbon will be consumed (333 pounds of $KMnO_4$ media per pound of VC). U.S. Filters estimates that 3.6 pounds of $KMnO_4$ media will be consumed per day of operations (assuming 0.16 ppmv VC and 270 scfm flow rate)[1] for the perched zone and 410 pounds of impregnated media consumed (assuming 21.75 ppmv VC and 224 scfm flow rate) [2] for the Expostion A and B zones (see attached email correspondence). The media costs approximately $2.00/pound excluding disposal. TN&A contacted John Lachance and Gorm Heron with TerraTherm as a reference for U.S. Filter's impregnated media (see TerraTherm Case Study).

1 Simulates expected operating conditions in the perched zone
2 Simulates expected operating conditions in the A and B exposition zone

<u>Calgon Carbon Corporation</u>
Calgon Carbon did not offer a special media designed for VC removal. Calgon provided a vapor phase virgin coconut shell and virgin coal carbon isotherm for VC removal (attached). Calgon estimated that 0.48 pounds of virgin coconut shell carbon will be consumed per day of operations (assuming 0.16 ppmv VC and 270 scfm flow rate) [1] for the perched groundwater zone and 21.20 pounds of carbon consumed (assuming 21.75 ppmv VC and 224 scfm flow rate) [2] for the A and B exposition zones.

3.0 TREATABILITY OF 1,4-DIOXANE VIA GAC

Data presented in the Final Feasibility Study and Technical Memo regarding the treatment of 1,4-Dioxane were inconclusive due to unavailable or limited isotherm data and no case studies. Recent isotherm modeling data provided by several carbon vendors indicates that GAC can be an effective technology for vapor phase treatment of 1,4-Dioxane (refer to the separate Technical Memo on 1,4-Dioxane treatment dated January 11, 2006). Furthermore, the limited detections of 1,4-Dioxane in the subsurface will not contribute to significant concentrations in extracted vapor, thereby making the treatability issue insignificant.

4.0 ANTICIPATED AIR EFFLUENT CONDITIONS

The South Coast Air Quality Management District (SCAQMD) is responsible for establishing vapor treatment equipment emissions concentrations for the Site that are protective of human health and the environment; i.e. considered "safe". The SCAQMD prescribed emission concentrations are based on the overall human health risk posed by the combined emissions of all contaminants in the vapor stream. The procedures for determining human health risks from air emissions sources are outlined in the SCAQMD Risk Assessment Procedures for Rules 1401 and 212. In order to comply with Rules 1401 and 212, the human health risk from the emission source must be less than that rate which is calculated to cause cancer in 1 person 100,000; or a cancer risk of 1×10^{-5}.

The SCAQMD air permitting department (Air Quality Engineer, Suparna Chakladar) assisted TN&A in modeling the maximum emissions rate for VC from the proposed Pemaco Treatment Compound given the following conditions: 1) 300 feet to residential receptors; 2) 90 feet to commercial receptors; 3) 12-foot high emissions point; 4) meteorological conditions using nearby City of Compton weather station data; and 5) air flow of 1500 SCFM. The SCAQMD model used the Risk Assessment Procedures for Rules 1401 and 212 to determined that in order to have a cancer risk less than 1×10^{-5}, the VC emissions concentrations could be no greater than 0.35 ppmv. This is considered a conservative number (actual limit will likely be higher) since the stack will be at least twice the height provided in the model. However, it is reasonable to approximate a VC effluent limit between 0.35 and 1 ppmv for the purpose of evaluating the feasibility of the GAC with potassium permanganate for vapor treatment.

[1] Simulates expected operating conditions in the perched zone
[2] Simulates expected operating conditions in the A and B exposition zone

5.0 CASE STUDY DATA

Case study data has been provided by Brian Dean of Earth Tech and John Lachance and Gorm Heron with TerraTherm. Both companies operated in-situ thermal projects (conductive heating) that utilized GAC followed by $KMnO_4$ media for vapor treatment. The TerraTherm Environmental Services Inc (TESI) system was designed to utilize GAC and $KMnO_4$ media for the entire project duration, which was less then one year. The Earth Tech system was designed to use a thermal oxidizer/scrubber for vapor treatment. However, the Earth Tech oxidizer/scrubber malfunctioned and GAC (alone) and GAC with $KMnO_4$ media vapor treatment technologies were used as a contingency plan for three months. A summary of the case study data that has been collected to date, appears below:

5.2 <u>TESI Case Study</u> (refer to the attached TESI Case Study Data for additional information)

The TESI vapor treatment system consisted of a series of two 5,000-pound GAC vessels followed by one 2,000 pound $KMnO_4$ media vessel.

- Influent VC concentrations ranged from 0.038 to 4.2 ppmv (low end of the 1 to 25 ppmv estimated "start-up" influent concentrations at Pemaco).
- Vapor flow rate range between 500 and 600 scfm.
- No specific air permit limit for VC.
- Data from the 7/22/05 sampling event shows achievement of the hypothetical 0.35 ppmv VC effluent limit using GAC. The two carbon vessels reduce the VC concentration from 4.2 to 0 14 ppmv (96.7% reduction). The $KMnO_4$ media vessel reduced VC concentrations from 0.14 ppmv to 0.076 ppmv (46% removal).
- Poor performance for VC removal was observed on the 8/15/05 sampling event due to reported condensation in the $KMnO_4$ media vessel (and possibly other vessels) This was likely caused by lack of insufficient vapor conditioning/humidity control.
- Data from the other two sampling events is incomplete to evaluate GAC performance for VC removal.
- Data from the 9/2/05 sampling event shows carbon was not effective in reducing VC (potential breakthrough) and poor performance of $KMnO_4$ media. The $KMnO_4$ media vessel reduced the VC concentrations from 0.56 to 0.42 ppmv (25% removal). Effluent discharge VC concentrations (0.42 ppmv) are within the hypothetical effluent limit range of 0.35 to 1 ppmv.
- Overall poor performance, with exception of 7/22/05 sampling event, may be attributed to the lack of vapor conditioning/humidity control.

5.2 <u>Earth Tech Case Study</u> (refer to the attached Earth Tech Case Study Data for additional information)

The Earth Tech treatment system consisted of a series of three 2,000 pound GAC vessels followed by two 2,000 pound $KMnO_4$ media vessels on the 3/14/05 sampling event and a series of four 2,000 pound GAC vessels (without the $KMnO_4$ media vessels) on the 5/17/05 sampling event.

- VC concentrations ranged from 9.1 to 16 ppmv (mid to high end of the 1 to 25 ppmv estimated "start-up" influent concentrations at Pemaco)

- Vapor flow rate range between 100 and 200 scfm (during the temporary GAC/$KMnO_4$ media operations).
- No specific air permit limit for VC.
- The GAC used was virgin coconut shell type.
- Data from the 3/14/05 sampling event shows achievement of the hypothetical 0.35 ppmv limit after 3 GAC vessels and 1 $KMnO_4$ media vessel. Three carbon vessels and one $KMnO_4$ media vessel reduced the VC from 16 to 0.2 ppmv (98.75% removal). The potassium permanganate vessel further reduced the VC to <0.0005 ppmv (>99.75% removal).
- Data point from 5/17/05 shows achievement of the hypothetical 0.35 ppmv limit after 3 GAC vessels. Three GAC vessels reduced VC from 9.1 to 0.00069 ppmv (99.99% removal).
- Vapor conditioning was not performed; vapor temperatures at the inlet of the carbon vessels were approximately 120° F and the relative humidity was reasonably high.
- There were occasional problems with low carbon efficiency due to moisture fouling.
- There was significant increase in headloss through the $KMnO_4$ media vessels over time.

6.0 CONCLUSIONS

Based on the information obtained from the carbon vendors and the references, TN&A believes that GAC followed by $KMnO_4$ media can be an effective technology for removing VC from the vapor phase with the following conditions: 1) the system is designed with a vapor conditioning package; 2) GAC consists of virgin coconut shell type; 3) the system is monitored frequently for breakthrough; and 4) redundant or standby vessels are included in the design.

The case studies were reflective of sites that did not have strict VC effluent limits; unlike Pemaco, which has an estimated VC effluent limit of 0.35 to 1.0 ppmv. There are operational uncertainties; including the potential for significant spikes in VOC concentrations during ERH and the possibility of VC competing with extracted alcohols and acetone for $KMnO_4$ media, that could result in exceedances of the VC effluent limits, or a requirement for more frequent sampling and carbon/$KMnO_4$ media change-out.

During the first nine months of remediation, the FTO is believed to be more reliable in treating high and/or variable VOC concentrations and VC. GAC with the $KMnO_4$ media technology is recommended for contingency use; e.g. in the event a disruption to the FTO operation, or after ERH when effluent vapor concentrations are on the decline and maximum concentrations are known

GAC technology is recommended for vapor phase treatment after the first nine months and/or after VC concentrations drop below effluent limits.

BAKER FILTRATION'S POTASSIUM PERMANGANATE MEDIA

Mike Berman

From: Joe Leslie [jleslie@bakertanks.com]
Sent: Tuesday, December 13, 2005 9:22 AM
To: Mike Berman
Subject: RE·
Attachments: TN&A Usage Calcs Vapor-224cfm.xls; TN&A Usage Calcs Vapor-270cfm.xls

Mike,

See the attached spread sheet that delineates carbon usage for the spread sheet that you sent me. As you can see the VC would be the driving force in each application, also notice that the acetone would not make using coal based carbon economically feasible.

If the KMN media was used in association with the carbon the usage rates based on the KMN concentrations and flow rates would be as follows:

1. Flow Rate = 270 scfm
   Vinyl Chloride = 0.16 ppmv
   Usage = 1.7lbs/day of KMN media
2. Flow Rate = 224 scfm
   Vinyl Chloride = 21.75 ppmv
   Usage = 73.5lbs/day of KMN media

Hope this helps out. I will work up a proposal for you including media pricing, service and vessel rental.

Regards,

Joseph Leslie
Sr. Sales Representative
Baker Filtration
4306 West 190th Street
Torrance, CA 90504
Ph. 310-303-3700 x110
Fax 310-406-3001
Email: jleslie@bakertanks.com
Web Site: www.bakertanks.com
Web Site: www.cameronenvironmental.com

From: Mike Berman [mailto:MBerman@tnainc.com]
Sent: Monday, December 12, 2005 4:37 PM
To: Joe Leslie
Subject:

Joe,
Please disregard the last table, here is the revised table.
thanks

Michael Berman, P.E.
Senior Engineer
TN & Associates, Inc.
317 E. Main Street
Ventura, CA 93001
Direct: (805) 585-6392

BAKER FILTRATION

A Division of BAKER TANKS

4306 West 190th Street, Torrance, CA 90504
Tel: 310.303-3700 ♦ Fax: 310.406-3001

Activated Carbon and Specialty Media
Pollution Control Systems and Filtration Equipment Rental

Fax Cover Sheet

To:	Mike Berman	From:	Joe Leslie
Company:	TN & Associates	Date:	December 8, 2005
Fax #:		Page:	1 OF 2
Phonc #:	805-585-6392	Quote #:	**4042TOR**
e-mail:	mberman@tnainc.com		

Mike,

Per our conversation, please find the following pricing on carbon vessels:

Item Description	Quantity	Unit Cost	Ext. Cost
•KA-2000S-HPV (Rental)	**2**	**$250/vessel/mth**	**$500/mth**
-Based on minimum rental period of 3 months			
•CEI-VCC Virgin CNS	**2,000lbs**	**$0.85/lb**	**$1,700.00**
-This is the initial fill for (1) vessel			
CEI-KMN Media	**4,000lbs**	**$1.35/lb**	**$5,400.00**
-This is the initial fill for (1) vessel. It has 2x the density of carbon so 72 cu. Ft. of the KMN media weighs 4,000lbs instead of 2,000lbs			
·Turnkey Vac/Rebed Svc (CNS)	**2,000lbs**	**$0.97/lb**	**$1,940.00**
OR			
·Turnkey Vac/Rebed Svc (KMN)	**4,000lbs**	**$1.47/lb**	**$5,880.00** KMnO4 Media cost
-Both assume Non-Haz Profiling			

Turnkey spent media service to include:

- Transportation of service equipment and personnel to job site from Torrance, CA.
- Pump spent media from filter units into super sacks.
- Refill filter units with desired media.
- Label non-hazardous spent filter media as required.
- Transport and disposal of non-hazardous spent media.
- Return transportation of service equipment and personnel from job site.

•Testing/Profiling	**2**	**$250.00**	**$500.00**

-(1) test for each media type. Assumes Non-Haz classification

*Taxes Not Included.

CAMERON
Environmental, Inc.

Activated Carbon & Pollution Control Systems

CEI-KMN Air Purification Media

Cameron Environmental's CEI-KMN, is a unique molecular sieve substrate utilized for odor, ethylene, and corrosion control. The media is impregnated with 6% potassium permanganate. This media provides 50% more active ingredients without the dust of alumia-based products.

Specifically designed to oxidize gaseous pollutants such as:

- Hydrogen Sulfide
- Sulfur Dioxide
- Formaldehyde
- Ethylene
- Mercaptans
- Various Aldeydes and Alcohols

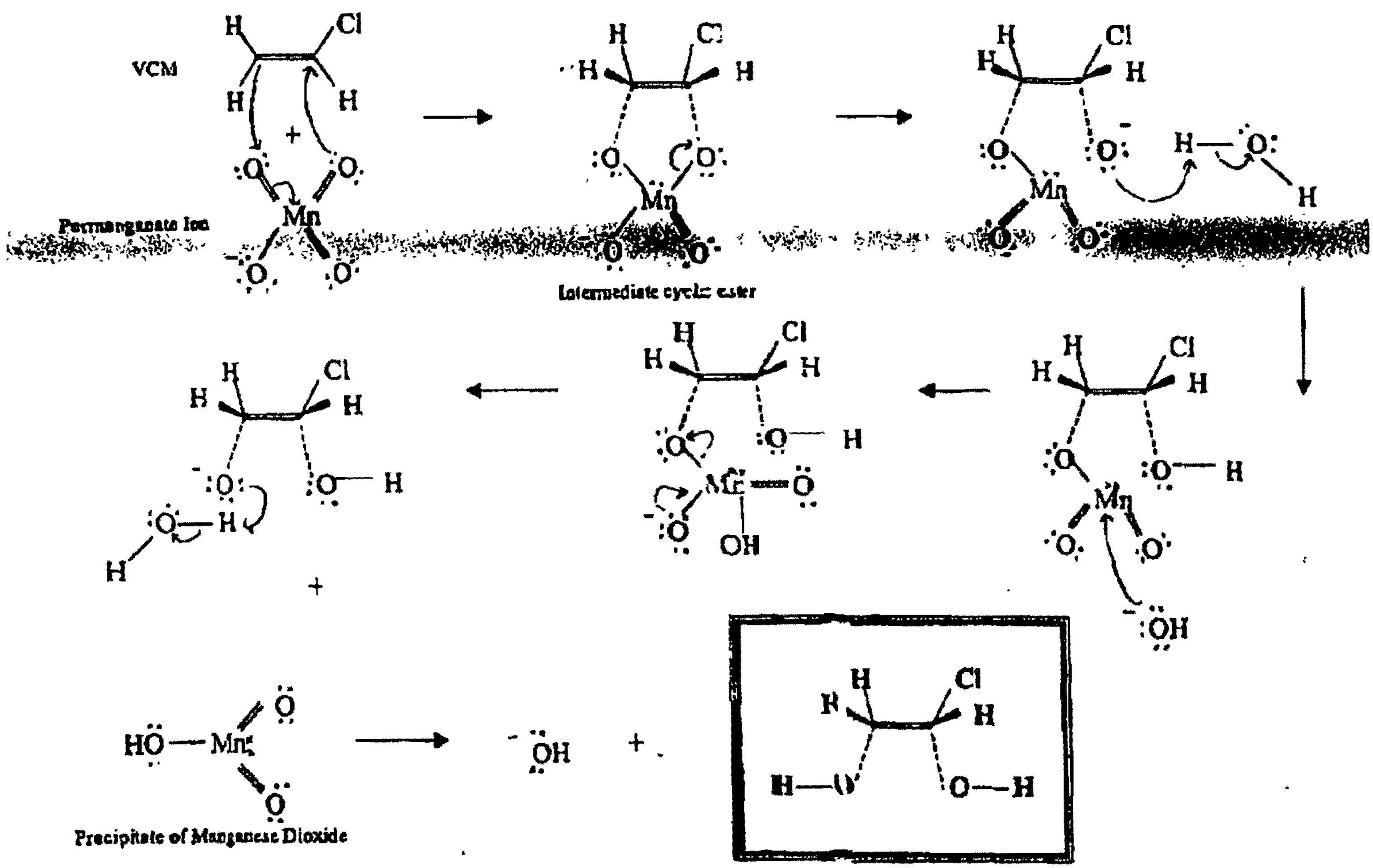
PHYSICAL PROPERTIES:

Cation Exchange Capacity:	2.20 meq/g
Bulk Density (lbs./cu.ft)	60 average
Hardness (Mohs scale):	5.1
Pore Size:	4.0A
Pore Volume:	15%
Surface Area (Internal):	1357 yd2/oz (40 m2/g)
Thermal Stability:	1202 F (650 C)
Crushing Strength:	2500 lbs./sq. in.
Mesh Size:	6x8

These specifications represent general parameters and are subject to change Please consult with CEI before proceeding with your applications

20741 Manhattan Place, Torrance, California 90501
Phone: 310.212.0610 ♦ Fax: 310.212.7222

Reaction Mechanism of Permanganate Ion with VCM (Vinyl Chloride Monomer)



Product : 1,2 dihydoxy, chloroethane

FIGURE 1

KMN Reactivity and Capacity

Chemical Compound	Efficiency Rating	Theoretical Capacity, weight %	Chemical Compound	Efficiency Rating	Theoretical Capacity, weight %
acetaldehyde	high	20.0	ethane	low	0.1
acetic acid	high	21.5	ether	high	15.5
acetone	high	18.4	ethanolamine	high	8.2
acetylene	medium	4.0	ethyl acetate	high	16.5
acrolein	high	19.3	ethyl acrylate	high	12.6
acrylic acid	high	20.0	ethyl alcohol	high	12.0
acrylonitrile	high	16.5	ethyl ether	high	15.5
ammonia	low	3.0	ethyl formate	high	16.5
amyl acetate	high	12.5	ethyl mercaptan	high	16.0
amyl alcohol	high	12.0	ethyl silicate	high	6.5
amyl ether	high	13.6	ethylene	medium	3.8
aniline	low	1.0	ethylene diamine	high	5.5
arsine	high	14.0	ethylene oxide	high	12.4
benzene	low	0.6	formaldehyde	high	23 6
borane	high	3.2	formic acid	high	27.5
bromine		32.0	heptane	medium	3.0
butadiene	medium	3.6	heptylene	medium	9 0
butane	low	0.5	hexane	medium	3.0
butanone	high	16.2	hexylene	medium	3.3
butyl acetate	high	17.5	hydrogen	high	0.8
butyl alcohol	high	15.3	hydrogen cyanide	high	8.0
butyl ether	high	14.5	hydrogen selenide	high	20 2
butylene	medium	3.2	hydrogen sulfide	high	14 5
butyraldehyde	high	16.2	indole	medium	3.2
butyric acid	high	17.5	iodoform	high	16.5
caproic acid	high	14.1	isoprene	medium	3.0
caprilic acid	high	15.7	isopropyl alcohol	high	13.0
carbon dioxide	low		isovaleric acid	high	12.6
carbon disulfide	low	1.5	keronane	medum	8.0
carbon monoxide	medium[1]	10.0	lactic acid	high	10.0
carbon tetrachloride	low		mercaptans	high	14.0
chlorine		19.3	methane	low	0.0
chloroform	low	5.0	methyl acetate	high	16.5
chloroprene	medium	5.0	methyl acrylate	high	12.7
crotonaldehyde	high	12.1	methyl alcohol	high	12.5
cyclohexane	medium	3.2	methyl ether	high	15.6
cyclohexanol	high	12.0	methyl ethyl ketone	high	18.4
cyclohexanone	high	12.5	methyl isobutyl ketone	high	17.2
cyclohexene	high	10.0	methyl mercaptan	high	16.0
decane	low	3.5	methyl cyclohexane	medium	3.3
diethylamine	high	5.5	methyl cyclohexanone	high	13.5
diethylene triamine	high	5.0	methyl chloride		5.0
diethyl ketone	high	12.5	nicotine	high	25.5
dimethyl sulfoxide	high	12.0	nitric acid		6 3

KMN Reactivity and Capacity

Chemical Compound	Efficiency Rating	Theoretical Capacity, weight %
nonane	low	3.0
octalene	medium	9.2
octane	low	3.0
palmitic acid	high	13.0
pentane	low	2.2
pentanone	high	14.8
pentene	medium	7.6
pentyne	high	6.7
perchloroethylene	low	0.1
phenol	high	16.2
phosgene	high	10.0
propane	low	0.5
propionaldehyde	high	14.1
propionic acid	high	14.7
propyl acetate	high	15.3
propyl alcohol	high	13.8
propyl ether	high	14.1
propyl mercaptan	high	15.2
propylene	medium	8.0
putrescine	high	15.0
pyridine	high	5.3
skatole	medium	4.3
stibine	high	22.4
sulfur dioxide	high	26.0
sulfur trioxide		
sulfuric acid		
tetrachloroethane		
trimethyl amine	hign	5.3
turpentine	medium	8.0
uric acid	high	22.5
valeric acid	high	14.8
valeraldehyde	high	13.9
xylene	low	0.6

These data are theoretical capacity estimates based on stoichiometric reactions between the chemicals and potassium permanganate. There are several factors that can affect this reaction and thus the actual capacity of KMN media for these chemicals. These factors include: relative humidity, airborne dust, contact time and other species in the air stream. CEI recommends that the end user test the KMN media to determine its capacity and efficiency for the removal of specific chemicals alone and in combination.

CAMERON
Environmental, Inc.

Activated Carbon, Pollution Control Systems, and Waste Management Services.

REACTION FOR THE REMOVAL OF VINYL CHLORIDE USING POTASSIUM PERMANGANATE

The reaction of permanganate ion with vinyl chloride monomer is outlined in Figure 1. The reaction produces 1,2 dihydroxy, chloroethane, an addition product, and a precipitate of manganese dioxide. A short description of the reaction is also included below. The typical oxidation reaction for an alkene by permanganate ion may be found in any general organic chemistry text.

The oxidation of an alkene leads to the formation of a compound with hydroxyl groups on the carbon atoms that were involved in the double bond, a 1,2 diol. Manganese (VII) in permanganate ion is ultimately reduced to manganese (IV) in manganaese dioxide. The carbon atoms of the double bond are oxidized. Even if no base is added at first, the solution becomes progressively more basic as the reaction proceeds.

In this oxidation reaction, the two hydroxyl groups become attached to the same face of the double bonds. The permanganate ion is believed to add to the double bond to give a cyclic intermediate, a manganate ester. The first step of this reaction is the syn (same side) addition of permanganate ion to the double bond. This intermediate breaks down in the presence of water to give the cis-1,2 diol. Thus, there are no appreciable quantities of chlorine gas or formaldehyde formed in the reaction.

20741 Manhattan Place, California 90501
Phone: 310.212.0610 ♦ Fax: 310.212.7222

U.S. FILTER'S POTASSIUM PERMANGANATE MEDIA

Mike Berman

From: Arriola, Heidy [ArriolaH@USFILTER.com]

Sent: Tuesday, December 20, 2005 5:04 PM

To: Mike Berman

Subject: RE: 1,4 dioxane isotherm.pdf

Attachments: Copy of carbon loading submittal (2).xls

Mike,

The carbon usage rates are provided below based on the attached spreadsheet. (Spreadsheet also contains some notes)

In summary there are two scenarios:

Scenario 1: Perched Groundwater

- Carbon usage Rate: 49 lbs/day
- Impregnated carbon usage rate to treat for Vinyl Chloride: 3.6 lbs/day*

Scenario 2: Combined A/B Zone

- Carbon Usage Rate: 277 lbs/day**
- Impregnated carbon usage Rate: 410 lbs/day*

*The impregnated carbon usage rates assume a minimum 8 second contact time in the vessel.
**This carbon usage rate assumes Carbon Disulfide will pass through the carbon. There are literature references that state potassium permanganate impregnated carbon will also oxidize carbon disulfide but we can't guarantee that. Since carbon disulfide is there at such low concentration, it is safe to ignore it in the carbon usage rates and assume it is going to be controlled by the impregnated carbon treatment system

In regards to 1,4 Dioxane, Dr. Graham strongly disagrees with the isotherms provided by our competitor. I am attaching the isotherms that he generated from our Isocalc program. If you would like to discuss further, please feel free to call me and we can get Dr. Graham on the phone. ☺

Thanks for your patience ☺
Heidy

Mike Berman

From: Arriola, Heidy [ArriolaH@USFILTER.com]
Sent: Tuesday, December 06, 2005 9:17 PM
To: Mike Berman
Subject: RE: Vinyl Chloride removal

Hi Mike,

It was good to talk to you again ☺
I'm glad that with your move we will still have the opportunity to work together.

In response to your questions...in order to estimate removal of Vinyl Chloride with Potassium Permanganate impregnated carbon we make the assumption that for every 0.3 lbs of Vinyl chloride to be removed you will need 100 lbs of media. However, this is assuming the following conditions are met:

- a contact time that is greater than 8 seconds,
- humidity (60 – 95%) in the air stream
- and a reasonable temperature (>70 oF)

The lower the temperature, the longer will be the contact time that is required to achieve this usage rate. With these things in mind, go ahead and use that assumption for estimating ball park usage rates.

For the concentrations you provided I was able to calculate the following media usage rates:

1000 cfm
20 ppm Vinyl Chloride – 1671 lbs of Impregnated Carbon/day
200 ppm Vinyl Chloride – 16,709 lbs of Impregnated Carbon/day

I will be out of the office for the remainder of the week with limited access to email and cell phone. If you have any questions, please leave me a message on my cell phone and I will call you back as soon as I get a chance.

I hope this helps!! ☺

Heidy

Heidy Arriola
Field Sales Engineer
USFilter/Westates
15319 Carmenita Road
Santa Fe Springs, CA 90670
800-659-1771 ext. 109
Cell 818-943-4253
Fax: 562-684-4121
e-mail: arriolah@usfilter.com
www.usfilter.com

From: Mike Berman [mailto:MBerman@tnainc.com]

Mike Berman

From: Arriola, Heidy [ArriolaH@USFILTER.com]
Sent: Thursday, December 22, 2005 5:32 PM
To: Mike Berman
Subject: RE:
Attachments: Hydrosil.doc

Hey Mike,

Its actually about $2.00/lb for change outs with this media not including disposal.

KMW04 Mediu Cost

I'm attaching some specs on it.

Heidy

Heidy Arriola
Field Sales Engineer
USFilter/Westates
15319 Carmenita Road
Santa Fe Springs, CA 90670
800-659-1771 ext. 109
Cell 818-943-4253
Fax: 562-684-4121
e-mail: arriolah@usfilter.com
www.usfilter.com

From: Mike Berman [mailto:MBerman@tnainc.com]
Sent: Thursday, December 22, 2005 2:46 PM
To: Arriola, Heidy
Subject:

Heidy,
What is a ball park cost per pound for turnkey service for the potassium permanganate media. If this goes, I will assume we will have 3,000 pound change outs. I think you told be $1.60 per pound before, but I would like to confirm.
Also, can you pdf or sent me a link to the technical cut sheet of the potassium permanganate media.
thanks

Michael Berman, P.E.
Senior Engineer
TN & Associates
317 E. Main Street
Ventura, CA 93001
Direct: (805) 585-6392
Fax: (805) 585-2111
mberman@tnainc.com

USFilter

Environmental Services | **Toll Free** 800.659.1771
15319 Carmenita Road | TELEPHONE 562.229 9606
Santa Fe Springs, CA 90670 | FACSIMILE 562.229.9322

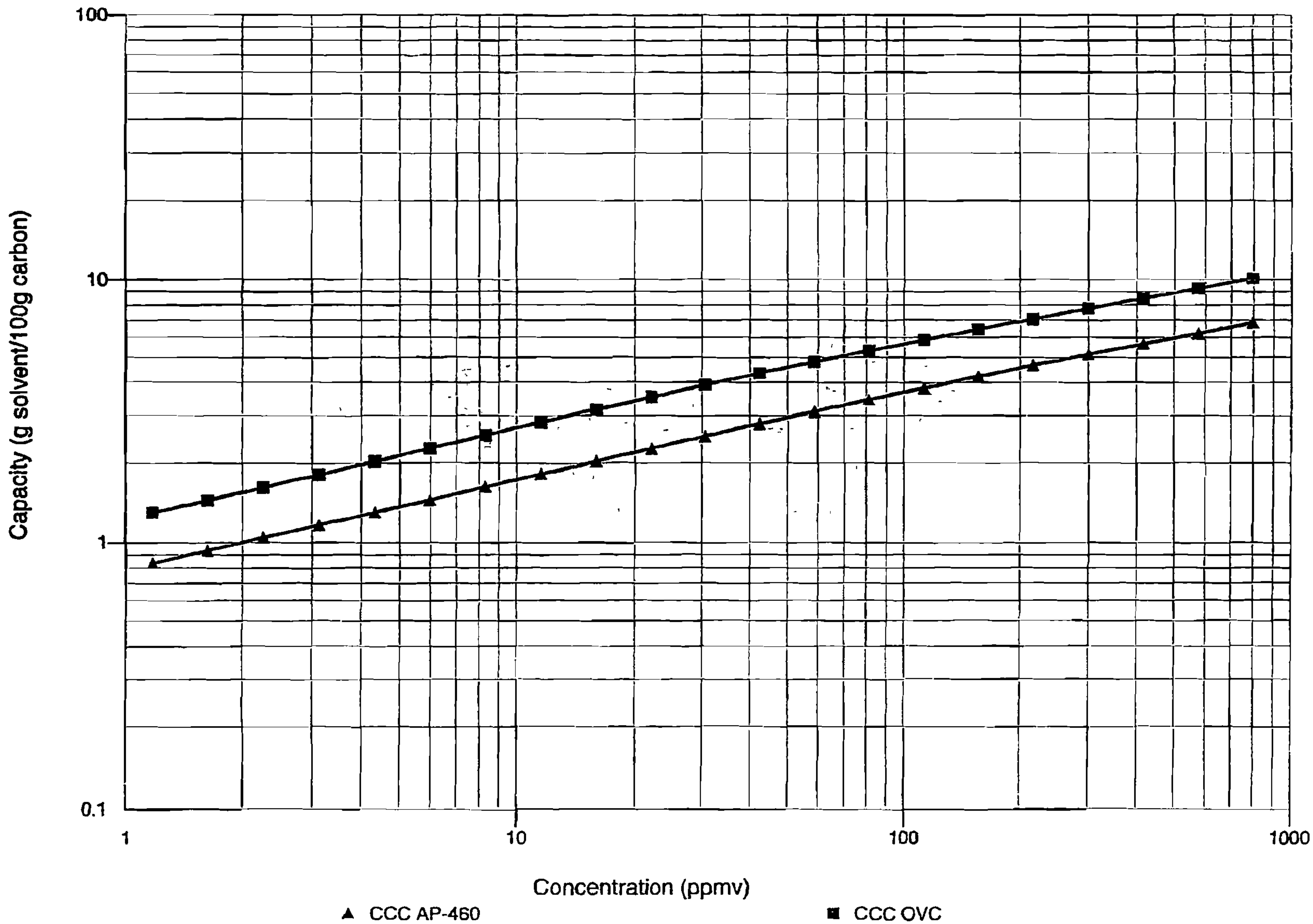
Hydrosil Impregnated Media

Active Ingredient	$KmnO_4$*
Substrate	Zeolite
Cation Exchange Capacity	Yes
Dusting	Insignificant
Attrition	Insignificant
Hardness of Substrate	Hard
Erosion in Air Stream	Insignificant
Particle Size	1/8" to 1/4"
Flammability	No
Bulk Density	60 lbs/ft^3
% Active Ingredient	6.0%
Pounds of Active Ingredient (1.0 cubic foot)	3.6 lbs (MnO_4/KOH/MnO_2)
Moisture Content	12 to 15%
Possible Combustion during Start-up	None
Color Indicator when spent	Yes

*Chemically $KmnO_4$ produces three ingredients: MnO_4, KOH, MnO_2

CALGON CARBON'S CARBON LOADING FOR VINYL CHLORIDE

Isotherm for Vinyl Chloride at 76 F and 1 atm



This information has been generated using Calgon Carbon's proprietary predictive model. The model provides an adsorbent use rate estimate based on the input conditions specified by the user. There is no expressed or implied warranty regarding the suitability or applicability of results.

Calgon Carbon Corporation VaporAds Report

Temperature (F): 76.0 Flow Rate (actual ft3/min): 270 12/19/05

Pressure (atm): 1.0

Adsorbate (Listed in Order of Elution-First is on Top)	Concentration (ppmv)	Adsorbent Use Rate (lbs/day) CCC AP-460	CCC OVC – VIRGIN			
Vinyl Chloride	0.16	8.258	5.623			
Acetone	0.12	7.509	5.144			
1,2-Dichloroethylene (trans)	1.03	4.375	3.135			
1,1-Dichloroethane	0.28	4.009	2.897			
Methyl Tertiary Butyl Ether	0.19	2.666	2.002			
1,1,1-Trichloroethane	0.2	2.557	1.929			
Tetrachloroethylene	1.634	2.242	1.712			
Toluene	0.2285	1.042	0.837			
Ethylbenzene	0.73	0.970	0.783			
Xylene (ortho)	1.068	0.788	0.641			
Totals:	5.64E0					

Note: This information has been generated using Calgon Carbon's proprietary predictive model. No safety factors have been incorporated into these results. Appropriate safety factors should be applied as necessary. There is no expressed or implied warranty regarding the suitability or applicability of results.

Calgon Carbon Corporation VaporAds Report

Temperature (F): 76.0 Flow Rate (actual ft3/min): 224 12/19/05

Pressure (atm): 1.0

Adsorbate (Listed In Order of Elution-First is on Top)	Concentration (ppmv)	Adsorbent Use Rate (lbs/day) CCC AP-460 Coal	CCC OVC – VIRGIN Virgin Coc.			
Vinyl Chloride	21.75	141.976	101.498			
Acetone	0.00577	108.945	80.295			
Carbon Disulfide	0.72	86.672	65.970			
1,2-Dichloroethylene (trans)	68	86.530	65.878			
Trichloroethylene	142.5	57.418	44.934			
Tetrachloroethylene	0.705	9.213	7.259			
Toluene	0.6525	0.750	0.605			
Ethylbenzene	0.003375	0.439	0.359			
Xylene (ortho)	0.0215	0.256	0.214			
Hexachloro-1,3-butadiene	0.2175	0.092	0.083			
Totals:	2.35E2					

Note: This information has been generated using Calgon Carbon's proprietary predictive model. No safety factors have been incorporated into these results. Appropriate safety factors should be applied as necessary. There is no expressed or implied warranty regarding the suitability or applicability of results.

TERRA THERM CASE STUDY DATA

T N & Associates, Inc.
Engineering and Science

Phone Record

PROJECT NAME: **Pemaco Superfund Site**

LOCATION: **Maywood CA**

DATE: **12/21/05** **TIME:** **10:40 AM**

FROM: **Mike Berman** **COMPANY:** **TN & Assoc.** **PHONE #** **(805)585-6392**

TO: **John Lachance** **COMPANY:** **TerraTherm** **PHONE #** **(978)343-0300**

SUBJECT: U.S. Filter's KMNO4 Carbon used for vinyl chloride removal at a chlorinated site treated by in-situ soil heating/SVE

DISCUSSION: Contacted TerraTherm regarding the use of $KMnO_4$ impregnated media for the removal of vinyl chloride from vapor phase. John with TerraTherm provided the following information:

- The vapor phase treatment system consisted of two 5,000 pound carbon vessels in series (for treatment of chlorinated hydrocarbons) followed by a polishing 2,000 pound vessel filled with $KMnO_4$ impregnated media (provided by U.S. Filters).
- The vapor phase flow rate ranged from 500 to 600 scfm.
- The treatment system operated for 4 months.
- Vinyl Chloride concentrations dropped off quickly (couple months).
- Condensation was found in the last potassium permanganate media vessel. The $KMnO_4$ leached into the condensate. To remedy this problem TerraTherm insulated the carbon vessels (to prevent heat loss).

Solution:

CONCLUSION: TerraTherm was content with the performance of the $KMnO_4$ impregnated media.

ACTION TO BE TAKEN: None.

COPIES TO:

TERRATHERM®

Commercial Brownfields Project: Terminal One Tank Farm

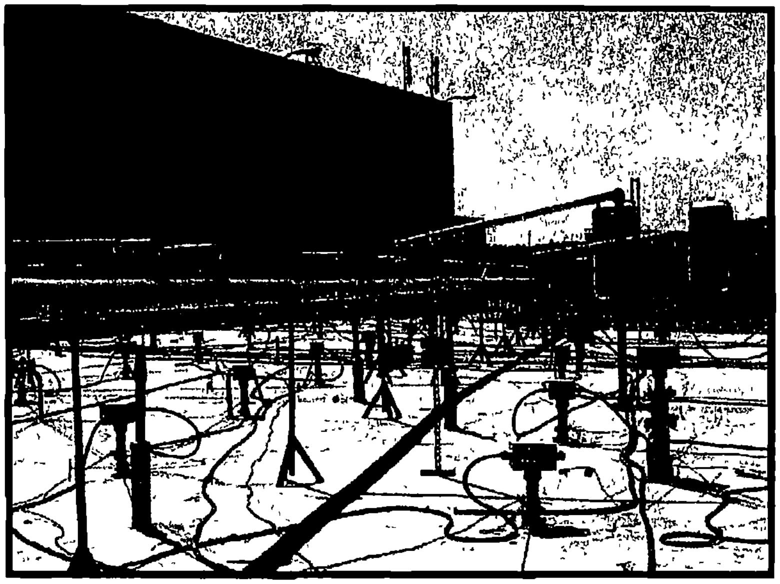
Project Location: Richmond, California

Owner: Richmond Redevelopment Agency

Consultant: Geomatrix Consultants

Time Frame: 2005

Site Information: The City of Richmond's 14-acre site, known as the former Terminal One, was operated as a shipping and bulk storage terminal from about 1915 to the 1980s. The portion of the property being treated is known as the "Southwestern Tank Farm" where solvents and petroleum products were stored in above ground tanks. The total treatment volume is approximately 6,700 cy; of which, a small portion is under a warehouse that will be demolished after the thermal treatment is complete. The Southwestern Tank Farm is slated to become a recreational area as part of a 250 unit residential community after site cleanup is completed.



ISTD Well Field

CoCs: Contaminants of Concern are as follows: tetrachloroethene (PCE); trichloroethene (TCE), *cis*-1,2 dichloroethene (DCE); and vinyl chloride (VC).

Soil Characteristics: Soils within the thermal treatment area are composed of Bay Mud, a dark greenish gray lean clay with minor amounts (<5%) of sand. A 2-3' layer of fill exists above the Bay Mud. Thin interbedded layers with abundant shells (a few inches thick) have also been observed. The average thermal treatment depth was approximately 20 feet below ground surface (bgs).

Groundwater: Depth to water beneath the site is approximately 3 feet bgs.

Summary of Results:

		PCE	TCE	cis-1,2-DCE	VC
		ug/kg	ug/kg	ug/kg	ug/kg
Remedial Goals		2,000	2,000	17,000	230
AVG	AVG Pre	34,222	1,055	6,650	932
	AVG Post	12 36	< RL	64 68	4.73
	No. of Samples <RL (i.e., ND)	54	64	41	63
	% Reduction AVG Pre to Post	99.96%	> 99.6%	99.03%	99.49%
MAX	Max Pre	510,000	6,500	57,000	6,500
	Max Post	44	< RL	1,500	24
	% Reduction Max Pre to Post	99.99%	> 99.2%	97.37%	99.63%

RL = Laboratory Reporting Limit

AVG = Average - calculated using detected values and the RL/10 for non-detects.

Project Approach: In-Situ Thermal Desorption (ISTD) remediation at the Southwestern Tank Farm includes the following design features: a) minimum target temperature of 100°C; b) 12.0-ft spacing between thermal wells; c) 139 thermal wells; d) vapor barrier; e) granular activated carbon and potassium permanganate for off-gas treatment.

Project Staffing: As General Contractor, TerraTherm, Inc., has provided all project design, construction, operation,and equipment.

Subcontracting: TerraTherm subcontracted for construction labor, drilling, and electricians.

Project Summary: Site mobilization occured in late January 2005. Site construction was completed in May 2005. Startup of the ISTD system occured on schedule in early-June 2005 and treatment was completed ***on time*** (100 days) and ***on budget*** in September 2005. ***All remedial goals met*** (see table above). Demobilization from the site was completed in November 2005.

	Product	Date	Pounds	
Initial Load/ Setup	GAC	18-Apr	10,000	2 x 5,000 lb vessels
	GAC w/ $KMnO_4$	15-Apr	2,000	1 x 2,000 lb vessel
	GAC	15-Apr	1,000	1 x 1,000 lb vessel
	GAC	10-May	2,000	1 x 2,000 lb vessel
	BioMin - Org. Clay Liq. Phase Treatment	15-Apr	200	1 x 200 lb vessel
			15,200	
Change Outs	GAC	27-Jun	5,000	
	GAC	14-Jul	10,000	
	BioMin - Org. Clay Liq. Phase Treatment	14-Jul	200	
	GAC	26-Jul	5,000	
	GAC and GAC w/$KMnO_4$	17-Aug	5,000	
	GAC	2-Sep	5,000	
	GAC	19-Sep	6,000	
	GAC	27-Sep	5,000	
			41,200	

All media purchased from: USFilter, Westates Carbon-Arizona, Inc.
11711 Reading Rd., Red Bluff, CA 96080
(530) 527-8918

$KMnO_4$/GAC - HS600 Potassium Permangante Media

Concentration units: ppb (v/v)	Chloromethane				Vinyl Chloride				Acetone				trans-1,2-Dichloroethene			
	7/22/2005	8/15/2005	9/2/2005	10/7/2005	7/22/2005	8/15/2005	9/2/2005	10/7/2005	7/22/2005	8/15/2005	9/2/2005	10/7/2005	7/22/2005	8/15/2005	9/2/2005	10/7/2005
Influent to Primary GAC	1500	2200	2200	590	4200	1600	510	38	6400	9400	8900	5600	480	330	120	20
Effluent from Primary GAC	1000	1300	NS	NS	2800	970	NS	NS	ND	7300	NS	NS	ND	450	NS	NS
Effluent from Secondary GAC	950	2100	1900	NS	140	2100	560	NS	ND	ND	32	NS	ND	ND	ND	NS
Stack - Effluent from GAC/KMnO4	600	950	1400	93	76	1300	420	26	ND	ND	66	100	ND	ND	ND	ND
Vapor Flow Rate at Time of Sampling SCFM	481	659	674	688												

Notes: 8/15/05, GAC/KMnO4 bed saturated with water, changed out 8/17

Concentration units: ppb (v/v)	cis-1,2-Dichloroethene				Benzene				Trichloroethene				Toluene			
	7/22/2005	8/15/2005	9/2/2005	10/7/2005	7/22/2005	8/15/2005	9/2/2005	10/7/2005	7/22/2005	8/15/2005	9/2/2005	10/7/2005	7/22/2005	8/15/2005	9/2/2005	10/7/2005
Influent to Primary GAC	28000	18000	7300	680	520	920	790	120	4400	2000	430	50	7700	3000	1100	210
Effluent from Primary GAC	6 9	26000	NS	NS	ND	1500	NS	NS	ND	4400	NS	NS	3 3	ND	NS	NS
Effluent from Secondary GAC	ND	9 2	59	NS	ND	ND	ND	NS	ND	ND	ND	NS	ND	3	ND	NS
Stack - Effluent from GAC/KMnO4	2.3	66	41	ND	ND	ND	ND	ND	ND	ND	ND	ND	2 7	3 6	ND	ND
Vapor Flow Rate at Time of Sampling SCFM	481	659	674	688												

Notes. 8/15/05, GAC/KMnO4 bed saturated with water, changed out 8/17

Concentration units: ppb (v/v)	Ethylbenzene				Xylenes (total)				4-Ethyltoluene				1,2,4-Trimethylbenzene				Tetrachloroethene			
	7/22/2005	8/15/2005	9/2/2005	10/7/2005	7/22/2005	8/15/2005	9/2/2005	10/7/2005	7/22/2005	8/15/2005	9/2/2005	10/7/2005	7/22/2005	8/15/2005	9/2/2005	10/7/2005	7/22/2005	8/15/2005	9/2/2005	10/7/2005
Influent to Primary GAC	32000	23000	3800	340	49000	35000	5500	450	480	820	240	88	420	770	330	120	59000	31000	6700	790
Effluent from Primary GAC	8.5	ND	NS	NS	14	ND	NS	NS	ND	ND	NS	NS	ND	ND	NS	NS	28	15000	NS	NS
Effluent from Secondary GAC	ND	25	13	NS	2	45	24	NS	ND	2 7	ND	NS	ND	2 8	2 8	NS	ND	23	13	NS
Stack - Effluent from GAC/KMnO4	3 4	33	14	4 2	6	59	27	8	ND	3.3	ND	ND	ND	2.6	3	ND	8.4	32	11	8
Vapor Flow Rate at Time of Sampling SCFM	481	659	674	688																

Notes: 8/15/05, GAC/KMnO4 bed saturated with water, changed out 8/17

EARTH TECH CASE STUDY DATA

T N & Associates, Inc.
Engineering and Science

Phone Record

PROJECT NAME: **Pemaco Superfund Site**

LOCATION: **Maywood CA**

DATE: **12/12/05** **TIME:** **10:00 AM**

FROM: **Mike Berman** **COMPANY:** **TN & Assoc.** **PHONE #** **(805)585-6392**

TO: **Tom Kerscher** **COMPANY:** **Envent** **PHONE #** **(714)296-7505**

SUBJECT: Baker Filtration's $KMnO_4$ media used for vinyl chloride Removal at a chlorinated site treated by SVE

DISCUSSION: Contacted Envent regarding the use of Baker Filtration's $KMnO_4$ media for the removal of vinyl chloride from vapor phase. Tom with Envent provided the following information:

- The $KMnO_4$ media was used on a system that Envent rented to EarthTech. The rental included an air permit and Envent reviewed the laboratory results to make sure the system met the permit conditions. The vapor phase treatment system consisted of three 1,000 pound carbon vessels followed by two 1,000 pound vessels filled with $KMnO_4$ media (five vessels in series).
- Tom recalls that influent Vinyl Chloride concentrations ranged from 10 to 20 ppmv and that concentrations dropped of within 2 to 3 months.
- The vapor phase flow rate was approximately 200 scfm.
- Tom recalled that the influent/effluent was sampled for vinyl chloride.
- Tom thought that the media worked well since the effluent SCAQMD permit limits were met. He recalled effluent Vinyl Chloride concentrations were very low.

CONCLUSION: Tom recalls the $KMnO_4$ media worked well but suggested that we talk to EarthTech to get more specific data such as change-out frequencies.

ACTION TO BE TAKEN: None.

COPIES TO:

From: Dean, Brian [mailto:Brian.Dean@earthtech.com]
Sent: Tuesday, January 10, 2006 12:11 PM
To: John Wingate
Cc: Mike Berman
Subject: RE: VC Treatment by GAC/KMnO4 Zeolite

Gentlemen:

I am forwarding some lab results from soil vapor samples for your information. The first set of results from March 2005 is from a combination of 3 GAC vessels and 2 KMnO4 zeolite vessels in series. The second set of results from May 2005 is from 4 GAC vessels in series only.

I have attached a short data table, with results and efficiencies. I have also attached specific pages from the lab reports, with the client information blacked out (client confidential).

Please note that although the KMnO4 zeolite vessels appeared to work initially, they also appeared to spend quickly Due to better than expected adsorption of the VC by the GAC, I elected to eliminate use of the KMnO4 zeolite material after consumption of the pre-purchased volume. I had pre-purchased three vessels or 12,000 pounds of the KMnO4 impregnated zeolite. Also, each 4,000-lb vessel greatly restricted vapor flow. We were unable to deliver much vacuum to the SVE piping when we had two of the KMnO4 zeolite vessels in series - had to operate the vacuum blower at the max amp rating.

Brian

-----Original Message-----
From: John Wingate [mailto:JWingate@tnainc.com]
Sent: Monday, January 09, 2006 3:12 PM
To: Dean, Brian
Cc: Mike Berman
Subject: RE:

Brian,

I realize you are short on time, we are primarily interested in Vinyl Chloride removal data - via GAC or KMn04 impregnated media. Summary tables fine at this point.

Thanks,

-John

From: Dean, Brian [mailto:Brian.Dean@earthtech.com]
Sent: Monday, January 09, 2006 2:50 PM
To: Mike Berman
Cc: John Wingate
Subject: RE:

Mike:

I am working on it today and will forward what I have by the end of today. I am not sure it will be particularly useful however. We were primarily using carbon to treat 1,2-DCA vapors. Our performance monitoring was on the overall system and was not focused on the permanganate

Soil Vapor Treatment Results
Using Combined Activated Carbon and Permanganate Zeolite
(3 GAC Vessels and 2 Zeolite Vessels Connected in Series)

VOC	3/14/05 Vapor Samples				
	Inlet	Inlet Last Vessel		Stack	
	(ppmv)	(ppmv)	Efficiency	(ppmv)	Efficiency
1,2-DCA	140	0.52	99.63%	0.015	99.99%
VC	16	0.2	98.75%	<0.0005	100.00%
TCE	20	0.12	99.40%	0.0044	99.98%

Soil Vapor Treatment Results
Using Activated Carbon Only
(4 GAC Vessels Connected in Series)

VOC	5/17/05 Vapor Samples		
	Inlet	Inlet Last Vessel	
	(ppmv)	(ppmv)	Efficiency
1,2-DCA	190	0.16	99.92%
VC	9.1	0.00069	99.99%
TCE	28	0.014	99.95%

-----Original Message-----
From: John Wingate [mailto:JWingate@tnainc.com]
Sent: Tuesday, January 10, 2006 12:42 PM
To: Dean, Brian
Cc: Mike Berman
Subject: FTO Vs GAC Comparison

Brian,
Thanks. Could you clarify the excel table a little:

1. Inlet last vessel - is this last GAC? So # 3 vessel. Or First zeolite #4 vessel? I take Stack to be after last zeolite (#5 vessel).
ET - It was inlet to last vessel, GAC or zeolite. So, in March 2005, it was after 3 GAC and 1 zeolite. You are correct about the stack. That sample was taken after the final zeolite vessel (3 GAC and 2 zeolite).

2. Change out schedule? When was last change before 3/14 sample and before 5/17 sample? More importantly, what was operating time prior to sample collection?

ET - I am looking up this information now; will get back to you. I conducted carbon change-outs approx. every 7-10 days.

3. What size were the GAC vessels? Was it virgin coconut or coal?
ET - GAC vessels were 2,000-lb, virgin coconut. Please note that because the zeolite is dense, the zeolite vessels were the same size as the 2,000-lb GAC vessels.

4. Confirm that zeolite was never changed out.
ET - Correct. I ordered 3 zeolite vessels up front. We connected 2 in series initially. As the treatment progressed, the lead zeolite vessel was found to do nothing to VOC concentrations in the field. It was then removed, and the spare zeolite vessel was added to the end of the series. Eventually, all three zeolite vessels were taken out of service, and one of the vessels was then replaced with GAC.

5. What air flow was being pushed through, did you perform vapor conditioning fro R.H or temperature? If you have influent R.H. or Temp data that would be helpful.
ET - Generally, the flow was between 100 and 200 scfm We were treating off-gas from the TerraTherm ISTD eletrical resistance heating program. Inlet vapors were warm, typically near 120 F. I have a lot of data relating to flow and temp; will forward a range and average. I don't have any RH data, but I imagine it was reasonably high. The vapor stream would cool off while passing through the GAC vessels, and condensate would accumulate in the bottom of the vessels. We had problems with low carbon efficiency due to moisture fouling.

6. What was the VC effluent permit limit? Send copy of permit if you have.
ET - The system was rented from Envent. It was sort of an emergency/temporary treatment system. Our thermal oxidizer/scrubber was damaged and out of service for 3 months. Because the subsurface was hot from the TerraTherm ISTD system, we needed a small vapor treatment system to prevent any fugitive release of steam from the ground. Envent had one pre-permitted blower package that allowed VC treatment - old Various Locations permit from SCAQMD. I can pass along, but it won't be representative of the conditions that SCAQMD would issue today. We did not obtain our own permit for the equipment - no time given the circumstances. We had to use a pre-permitted package. I recall that the permit limit was 35 ppmv into the last vessel There was no specific limit for VC. Because the permit conditions were old, we were also working to make sure that our emissions were below OSHA PELs (for on-site worker protection).

7. did you buy zeolite from Baker Filtration?
ET - Yes.

Thanks again,

-John